Проведено порівняльний аналіз ефективності алгоритмів адаптивних антенних решіток при рухомих джерелах сигналів, що характерно для систем WIMAX. Надано рекомендації по выбору алгоритма при нестаціонарній сигнально-завадовій обстановці та кількості антенних елементів

Ключові слова: WiMAX системи, MBMB, елементів антени, СПО

Проведен сравнительный анализ эффективности алгоритмов адаптивных антенных решеток при движущихся источниках сигналов, что характерно для систем WIMAX. Даны рекомендации по выбору алгоритма при нестационарной сигнально-помеховой обстановке и количеству антенных элементов

Ключевые слова: WiMAX системы, MBMB, элементов антенны, СПО

A comparative analysis of efficiency of algorithms adaptive antenna arrays at the moving signals source, which is typical for systems WIMAX.Recommendations on the choice of the algorithm in nonstationary signal-noise conditions and the number of antenna elements

Keywords: WiMAX system, MIMO, the antenna elements, SINR

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WIMAX-TECHNOLOGY FOR BROADBAND WIRELESS ACCESS. BEAMFORMING OR AAS TECHNOGIES

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Preface and Acknowledgements

WiMAX technology is presently one of the most promising global telecommunication systems. Which is a Broadband Wireless Access System having many applications: fixed or last-mile wireless access, backhauling, mobile cellular network, telemetering, etc.

WiMAX is based on the IEEE 802.16 standard, having a rich set of features. This standard defines the Medium Access Layer and the Physical Layer of a fixed and mobile Broadband Wireless Access System. WiMAX is also based on the WiMAX Forum documents.

The creators of WiMAX consider the following aspects the most important criteria for evaluating equipment:

- The possibility of providing good coverage in the absence of line of sight;
- Submitting of transmission channel with the possibility of dynamic regulation over the time;
- Providing greater coverage at limited frequency resources (efficient use of frequencies);
- Effort high speed of transmission at the same time with good coverage at limited frequency resources.
- Quality of Service QoS at all these boundary conditions.

However the quality of service, high speed transmission can often be reduced due to several factors, one of these problems is electromagnetic compatibility (EMC).

Density distribution of WiMAX led to necessity use the same frequency band for different wireless networks, including those relating to different services. Naturally, in such a situation between wireless systems, relating to different services, there are mutual noises.

Electromagnetic environment (EME) complicates the fact that in this environment makes various random factors, which has unpredictable nature. In these circumstances to calculate in advance EME and EMC to solve the problem with sufficient accuracy is not always possible because of the expected uncertainty. All this does not allow directly use the classical methods and methodology software of EMC.

Therefore, at the moment appears actual task analysis of immunity systems, using WiMAX-technology and develop practical proposals to secure the EMC data systems.

Main Part

1. Beamforming or AAS Technologies

Beamforming technologies may be encountered behind several wordings: smart antenna, beamforming and Adaptive Antenna System (AAS). In the following beamforming will be used. The main objective of beamforming technology is to take benefit from the space/time nature of the propagation channel. Indeed, due to multiple reflections, diffraction and scattering on the transmitter to receiver path in a cellular environment, the energy reaching the BS comes from multiple directions, each direction being affected by a different attenuation and phase. In a Macrocellular environment (i.e. the antenna of the BS is above the rooftop) the signals reaching the BS are inside a cone. The angular spread of the signal depends on the environment. In a urban environment, the angular spread is of the order of 20 degrees. In a more open environment, like in a rural environment, the angular spread is a few degrees. In the uplink, the beamforming technology principle is to coherently combine the signals received for N antenna elements of an antenna array. A generic beamforming diagram is shown in Fig. 1. A block diagram of a beamforming receiver (respectively transmitter) with an *N*-element antenna array is shown in Fig. 1 (respectively Fig. 2). In the case of a block diagram of a beamforming receiver with an *N*-element antenna array, a signal processing unit analyses the same signal received from the *N* antenna elements and computes weights (w_i) that are applied on each path for combining [2,3].

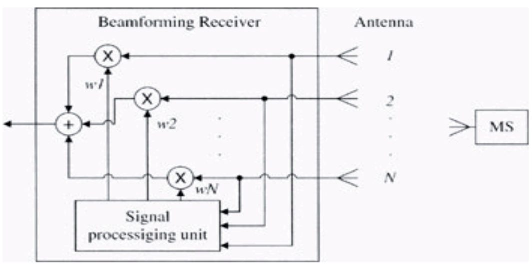

Fig. 1. Example of a block diagram of a beamforming receiver with an *N*-element antenna array

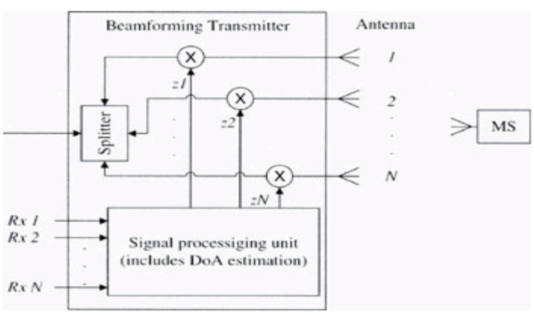

Fig. 2. Example of a block diagram of a beamforming transmitter with an *N*-element antenna array

On the downlink, the processing is very similar to the uplink. Based on the information measured on the signal received in the uplink, it is possible to estimate the Direction of Arrival (DoA) from the uplink signal and to apply different weights, z_i (amplitude and phase), to the different transmit paths of the same signal, so that the resulting antenna pattern focuses towards the direction of the user.

Since the weights in the downlink depend on the uplink signals, this assumes certain channel reciprocity between the uplink and downlink signals since the BS do not know the downlink spatial channel response. Actually, the reciprocity can more realistically be assumed in the case of the TDD system since the uplink and downlink signals use the same frequency at different time intervals. On the FDD system, the reciprocity is more difficult to assess.

In fact, beamforming technology encompasses several techniques. First implementations of beamforming were based on simple antenna switching mechanisms: in that approach, the elements of the antenna array where simply switched on or off according to the received signals. This has the advantage of simplicity but the possibility for beamforming is limited. Today, beamforming uses an adaptive array: the amplitude and phase of each antenna element can be set independently. This has the advantage of having the possibility to achieve infinity of beams.

With adaptive beamforming, several optimizing strategies may be used. The signal processing unit must maximize the received CINR. This can be achieved by having a resulting antenna pattern such that the antenna array creates a null in the direction of arrival of a strong interferer. However, the numbers of interferers that can be cancelled are limited by the number of elements constituting the array: with N antenna elements, it possible to have at most null *N*–1 interferers. In addition, this technique requires a good knowledge of the radio environment (which may imply additional overheads). This explains why in many implemented systems this method is mainly used in the uplink, where the BS can have maximum knowledge of the radio environment.

Finally, an advanced implementation of beamforming can enable SDMA (Spatial Division Multiple Access). Provided that two or more users are sufficiently separated in space, it is possible to send them at the same time, on the same physical resources, different information on different beams. Nevertheless, the use of SDMA is quite difficult in a mobile environment where MSs that may be well separated at a given moment may be in the same direction at the next moment.

2. MIMO (Multiple-Input Multiple-Output) Solution

MIMO systems use multiple input and multiple output antennas operating on a single channel (frequency). At the transmitter side, the signal is space–time encoded and transmitted from N_T antennas. At the receiving side, the signals are received from N_R antennas (see Fig. 3). The space – time decoder combines the signal received by the N_R antennas and transmitted from the N_T antennas after having estimated the channel matrix ($N_T \times N_R$).

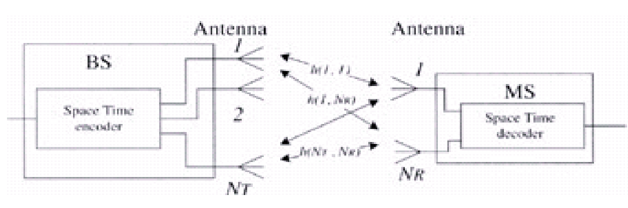

Fig.3. Generic MIMO block diagram for the downlink

The objective of the MIMO solution is to exploit the space and time diversity of the channels on the different radio paths between each combination of transmit/receive antennas to improve the reception sensitivity and/or to improve the channel capacity. There are several families of MIMO solutions. The two extreme ones are the spatial diversity MIMO schemes and the spatial multiplexing MIMO schemes. Spatial diversity MIMO refers to solutions where the same information is transmitted (after space–time coding) in space and time. The theoretical diversity gain of such a solution is a function of the product of the transmit/receive antennas and is equal to $N_T \times N_R$. For instance, a MIMO system implementing four antennas at the BS side and two antennas at the MS side has a diversity gain of 9 dB. An example of such a scheme is the Alamouti space–time code (STC). The space–time code of this 2×1 solution is given by the following matrix: $A=\begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix}$

In matrix A, S_1 and S_2 are the symbols to be transmitted over the air. At symbol k, symbol S_1 is transmitted from antenna 1 and S_2 is transmitted from antenna 2. At symbol k + 1, symbol $-S_2^*$ is transmitted from antenna 1 and symbol S_1^* is transmitted from antenna 2 S_i^* is the complex conjugate of symbol S_i).

Spatial Multiplexing (SM) MIMO refers to solutions where, during a symbol interval, different information is sent in parallel on different antennas. With this scheme, theoretically the capacity increases linearly as a function of N, N being the minimum between N_T and N_R. An example of the space–time code of such a solution is given by the following formula for a 2×2 SM scheme: $B=\begin{bmatrix} S_1 \\ S_2 \end{bmatrix}$.

With the SM code, the capacity of the channel and the burst transmitted rate are increased. However, this only happens under very good CINR conditions and a highly uncorrelated channel.

In addition, several MIMO schemes exist that are a mix between SM and spatial diversity schemes. The diversity order and capacity increase depends on the space–time code and number of antennas.

More recently, MIMO schemes using pre-coding have been defined. In these cases, the space–time code depends on a feedback from the receiver on the channel states. Indeed, this solution requires a closed-loop operation and additional signaling between the receiver and the transmitter.

Finally, MIMO can also be generated from signals transmitted from different BSs (virtual MIMO). This requires time synchronization of the BS but also a synchronization of the scheduler of the BS involved in the transmission.

Intelligent Multi Antenna are the basic system of Space-Time Signal Processing (STSP), under which, in general understand some set of operations on signals received at different points in space, allowing the highest quality extract contained in them useful information.

However, the algorithms AAS mainly designed for steady-state Signal-Noise Environment (SIE) [4]. AAS Application for Mobile WiMAX can reduce the effectiveness of these algorithms. With this purpose the algorithm is synthesized and analyzed based on the Kalman filtration for non stationary SIR.

At non steady-state SIR occur Space-Time changes the parameters of the signal and noise. These changes may occur due to the effects of high-frequency propagation environment, moving the receiver or transmitter, noise and other causes. For this SIR equation of state of Vector Weight Coefficients (VWC) has the form [4]:

$$\frac{d\widehat{w}(t)}{dt}=F(t)\widehat{w}(t)+P(t)H(t)N_v^{-1}\left[H(t)\widehat{w}(t)-y(t)_э\right], \quad (1)$$

Where $y(t)_э$ - reference value of wanted signal, $H(t)$ - matrix of the input signals $P(t)$ - matrix of the Dispersion of the Estimate of a Posteriori $\widehat{w}(t)$, determined from the Riccati equation:

$$\begin{aligned}\frac{dP(t)}{dt}&=F(t)P(t)+P(t)F^T(t)-\\&-P(t)H(t)N_v^{-1}H(t)P(t)+G^T(t)N_uG\end{aligned}. \quad (2)$$

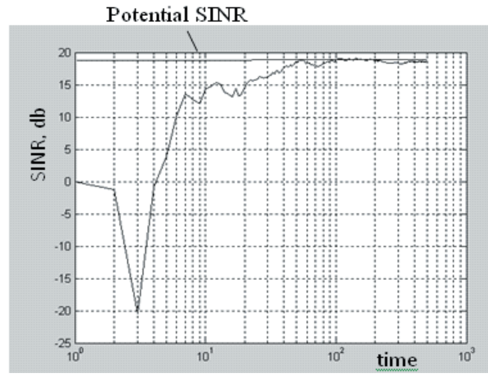

Fig.4. Relationship SNR output 4 AAA elements

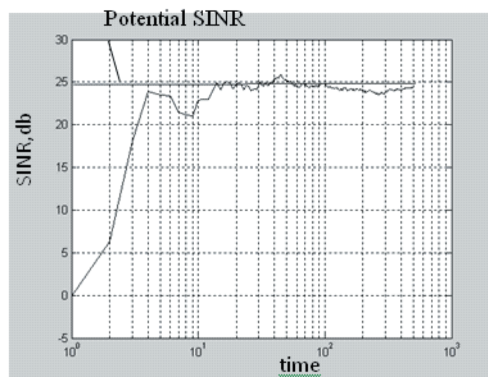

Fig. 5. Relationship SNR output 8 AAA elements vrs time for Kalman algorithm vrs time for Kalman algorithm

Despite the outward similarities with the Kalman algorithm, making (1), (2) fundamentally different in that the values of the Estimate of A Posteriori $P(t)$ were dependent on the observation results.

With the help of simulation analysis of the speed of convergence and effectiveness of noise reduction by the algorithm.

The initial data were taken the following values: the initial signal arrival angles $\Theta_c=0$ degrees, noise $\Theta_n=30$ degrees. Changing the angle of arrival of signal and noise at each step, respectively, for 4-element antenna system 4.6 $\cdot 10^{-4}$ degree, for 8-elements antenna system 0.0025 degree, for 16-element antenna system 0.0158 degree .Energy relations were selected appear next: Signal to noise ratio $\frac{P_s}{P_n}=13$ db, Signal to Interference ratio $\frac{P_s}{P_i}=0$ db, SINR at input of AAA is as $\frac{P_s}{P_n+P_i}=$ -0.2 db.

At fig. 4, fig. 6 represents the response to time SINR on o/p of 4, 8 and 16 elements AAS accordingly to Kalman algorithm. As appear from given curves adaptation time is from 10-th to 40-th steps, which is quite acceptable for WiMAX. At reaching its potential value SNIR within the detuning VWC, which is a control parameter in the process of adaptation and retention of the desired optimal value in the sense of minimum mean-square deviation of the received signal from a given (reference).

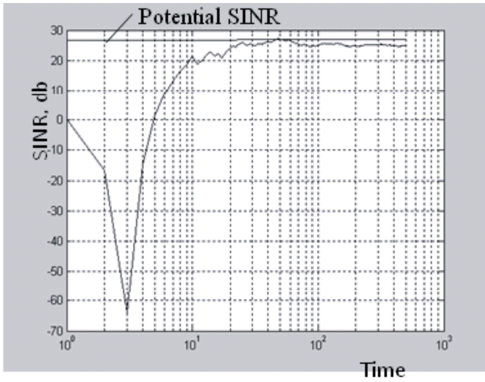

Fig. 6. Dependence SINR output a 16-element

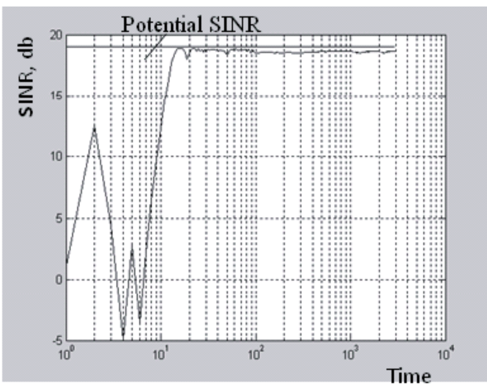

Fig. 7. Dependence SINR output 4 AAA element of time AAA on time for the Kalman algorithm for the Kalman algorithm for 3000 steps of recursion

Was conducted as an analysis of the effectiveness of this algorithm the length of his work. Fig. 7 shows curve of SINR vs. time at the number of antenna elements $N=4$ at 3000 steps recursion. Judging from this graph we can say, that over time at a sufficiently large change in the dynamics of the SIR effectiveness of Kalman algorithm remains stable and close to potential.

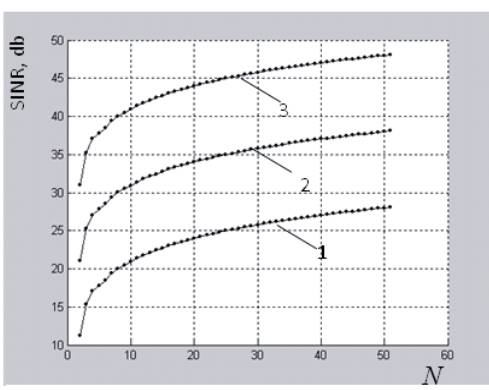

Fig.8. Dependence SINR at the AAA output of the number of antenna elements for different values of signal to noise

From Fig. 4 - Fig. 6 also shows that the number of antenna elements increases the efficiency of the algorithm. Therefore we conducted research of Depending on the effectiveness of the Kalman algorithm on the number of antenna elements.

Fig. 8 shows graphs of SINR depends on the number of antenna elements N at a significant signal/ interference ratio $\frac{P_s}{P_i}=0$ db, at different signal/noise $\frac{P_s}{P_n}$.Curve 1 fig8 corresponds to $\frac{P_s}{P_n}=10$ db, curve 2 corresponds to $\frac{P_s}{P_n}=20$ db and, curve 3 corresponds to $\frac{P_s}{P_n}=30$ db. Analysis AAA small and large dimension shows that with increasing number of antenna elements, effectiveness of noise reduction first increases sharply, and then this growth is reduced and becomes proportional to the number of elements N .As the analysis has shown that SINR at the AAA output essentially depends on the signal / noise at the input.

Thus, for WiMAX systems can be recommended algorithms AAA, synthesized by the methods of Kalman filter forming VWC with the number of antenna elements of 4 ... 16.

Conclusion

1. Algorithms AAA mainly designed for stationary source signals. Application of AAA for WiMAX can reduce the effectiveness of these algorithms. In order to establish the effectiveness of algorithms AAA analysis algorithms efficiency in AAA moving signal sources.

2. The analysis of the effectiveness of the algorithm, synthesized based on the Kalman filter for nonstationary SIR. Analysis showed that the adaptation time of the algorithm varies from 10 to 40-cc steps. At reaching its potential value SINR within the detuning of VWC, which is a control parameter in the process of adaptation and retention of the desired optimal value in the sense of minimum mean-square deviation of the received signal from a given (reference).

3. The analysis of the effectiveness of the algorithm on the number of antenna elements. Analysis of AAA small and large dimension shows, that an increase in the number of antenna elements, effectiveness of noise reduction first increases sharply, then this growth is reduced and becomes proportional to the number of elements N . The same analysis showed that SINR at the AAA output essentially depends on the signal / noise at the input.

4. For systems WiMAX is recommended to use algorithms AAA, synthesized by the methods of Kalman filter forming VWC with the number of antenna elements equal to 4 ... 16.

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